The Journal of Research on the Lepidoptera 22(2): 135-153, 1983

Conservation and Management of the Endangered Smith's Blue Butterfly, *Euphilotes enoptes smithi* (Lepidoptera: Lycaenidae)

Richard A. Arnold

Department of Entomology, 201 Wellman Hall, University of California, Berkeley, CA 94720

Abstract. *Euphilotes enoptes smithi* (Mattoni), commonly known as the Smith's blue butterfly (Lepidoptera: Lycaenidae), was among the first insects to be officially recognized as endangered species by the U.S. Fish & Wildlife Service. At the time of its listing in 1976, little was known about the distribution, ecology, and life history of *smithi*. Since 1977, I have intensively studied two populations at Fort Ord, a U.S. Army base near Monterey, California, using a combination of capture-recapture, life table and stage-frequency analysis techniques. Results of these studies are reviewed and preliminary management policies are discussed.

Introduction

Six California lycaenids were recognized as endangered species (U.S. Fish & Wildlife Service, 1976; Arnold, 1981), in accordance with the Endangered Species Act of 1973 (hereafter abbreviated as ESA 1973). The Smith's Blue butterfly, *Euphilotes enoptes smithi* (Mattoni), is endemic to coastal Monterey County, California. A primary purpose of ESA 1973 is to conserve endangered ("a species which is in danger of extinction throughout all or a significant portion of its range") and threatened ("any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range") species by instituting procedures which aid their recovery and survival. However, little information was available on the distribution, environmental requirements, life history and autecology of *smithi* when it was listed. Langston (1963) listed 5 known sites where *smithi* had been collected and noted that its foodplant at these sites was *Eriogonum parvifolium* Sm. in Rees (Polygonaceae). *Eriogonum* is commonly known as buckwheat. Other published accounts have been anecdotal or casual in nature.

Effective management or conservation programs must be based on knowledge of the biological and ecological requirements of an organism. Since 1977 I have intensively studied two *smithi* populations using capture-recapture, life table, and stage-frequency analysis techniques. Results of these studies are reviewed and preliminary management

policies are discussed. Conservation actions are presented in the format of a recovery plan of the Office of Endangered Species, U.S. Fish & Wildlife Service (OES/USFWS).

Taxonomy

The Smith's Blue butterfly was originally described in the genus *Philotes* by Mattoni in 1954. Shields (1975) realigned several genera, resulting in the placement of *enoptes* in the genus *Shijimiaeoides*. The scientific name of the Smith's Blue when it was listed as an endangered species in 1976 was *Shijimiaeoides enoptes smithi*. Mattoni (1977) subsequently made a number of nomenclatural rearrangements in several genera of Scolititandini, which resulted in the placement of *enoptes* in the genus *Euphilotes*.

The following morphological characters may be used to distinguish *smithi* from other infraspecific taxa of *Euphilotes enoptes* (Fig. 1): 1) the wide marginal band on the dorsal forewings of males, 2) the faint terminal line on the underside of both wings, 3) the prominent checkering of the forewing fringe on both dorsal and ventral facies, and 4) a light underside with large, prominent macules (Langston, 1963).

Distribution

Euphilotes enoptes is known from the Rocky Mountains to the Pacific Coast (Howe, 1975). Although widely distributed, colonies are usually isolated and found in association with the larval foodplant, several species of *Eriogonum*.

Mattoni (1954) described *Euphilotes enoptes smithi* from material collected by himself and Claude Smith at Burns Creek, near California State Highway 1, Monterey County, California. Two colonies were known at the time of its description. Langston (1963, 1965) noted the occurrence of several additional colonies. During 1977-1981, I systematically surveyed coastal sand dunes of Monterey County to delineate the butterfly's geographic range. It is apparent that *smithi* is more widespread than earlier believed. In addition B. Walsh (pers. comm.) and L. Turner (*in litris*) discovered *smithi* colonies in the coastal mountains of Monterey County.

Emmel and Emmel (1973) noted a population of *E. enoptes* which resembles *smithi* from the region of Ojai and Santa Paula, Ventura County. They speculate that *smithi* may possibly occur in coastal Santa Barbara County. However, R. H. T. Mattoni (pers. comm.) believes that these individuals more closely resemble *E. enoptes tildeni* Langston than *E. enoptes smithi*. Farther north, M. Smith (1978) reported a colony of *E. enoptes* near *smithi* located south of Mount Loma Prieta, Santa Cruz County. Unfortunately much of the interior coastal montane regions of Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara Counties is rather inaccessible, thus there are few records from these areas. Undoubtedly numerous as yet undiscovered *smithi* colonies will be found in

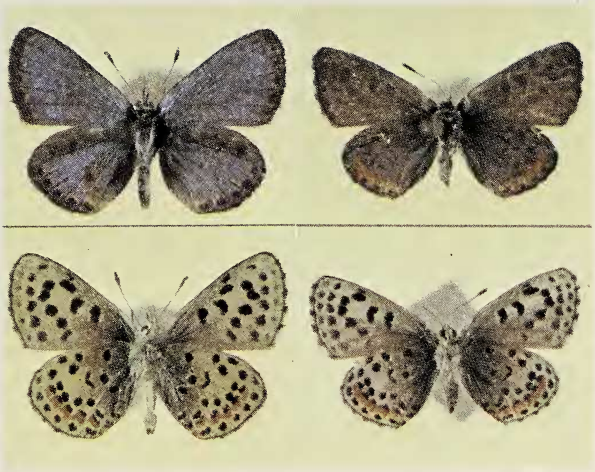

Fig. 1. Male and female of *Euphilotes enoptes smithi*: **a)** male dorsal wing facies, **b)** female dorsal wing facies, **c)** male ventral wing facies, and **d)** female ventral wing facies.

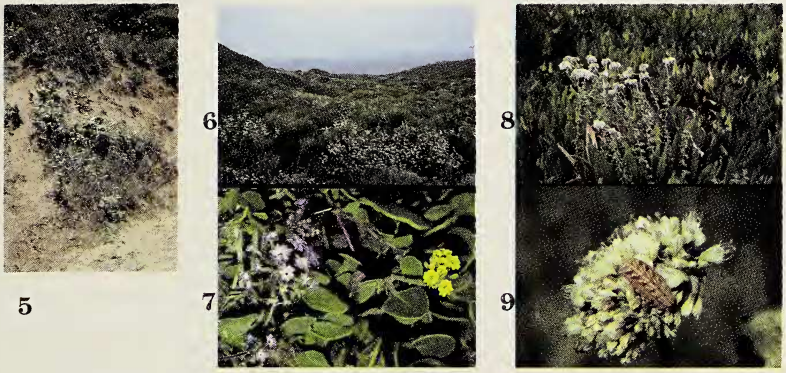

Fig. 5. *Eriogonum latifolium*, larval and primary adult foodplant of *Euphilotes enoptes smithi* at NP.

Fig. 6. *Eriogonum parvifolium*, larval and primary adult foodplant of *Euphilotes enoptes smithi* at SP.

Fig. 7. *Mesembryanthemum edule* choking out *Eriogonum parvifolium* at SP.

Fig. 8. *Abronia latifolia* Eschs. and *A. umbellata* Lam. growing side-by-side at the California Department of Fish & Game's Ecological Reserve (locality number 13 in Fig. 2). *A. latifolia* generally has a more northern distribution while *A. umbellata* has a more southern distribution. The distribution of both species overlaps along the central California coast.

Fig. 9. Fourth instar larva of *Euphilotes enoptes smithi* feeding on *Eriogonum latifolium* flowerhead.

this region. Figure 2 depicts former and presently known localities for *Euphilotes enoptes smithi.*

Reasons for Decline

Although *smithi*'s range is considerably greater than previously believed, significant loss and alteration of its coastal sand dune habitat has occurred through urbanization, industrialization, agriculture, recreational and military activities. Housing and commercial developments, sand-mining, and highway construction have destroyed habitat, especially on the Monterey peninsula. North of Monterey, farming (artichokes and strawberries) and recreational activities (public beaches and off-road vehicles) have destroyed or degraded habitat. At Fort Ord and elsewhere, *Mesembryanthemum edule* L., *M. chilense* Mol. and *Ammophila arenaria* (L.) Link have been planted as ground covers to stabilize the normally shifting sand dunes. Large portions of these dunes are now dominated by alien plants which hinders establishment and growth of native dune vegetation, including *Eriogonum.* In the immediate area surrounding the city of Monterey, sand dunes formerly covered approximately 600^2 km (Powell, 1981). Over 50% of this habitat has been destroyed by man.

Coastal montane habitats for *smithi* have been less severely impacted to date because of the generally rugged and inaccessible terrain characteristic of the coastal mountains from Santa Cruz south to Santa Barbara. Nonetheless, some areas have been altered by grazing, off-road vehicle, logging and construction activities.

Habitat Description

A coastal sand dune is one of nature's more fragile habitats. Endemic fauna and flora are extremely susceptible to habitat disruption. Powell (1981) reviewed the threats to survival for coastal California insects endemic to sand dunes, whose numbers are diminishing due to widespread loss and degradation of habitat. Dune vegetation is easily damaged by foot (Hylgaard, 1980; Hylgaard and Liddle, 1980) and vehicular traffic (Seneca, 1980).

Fig. 2. Distribution of known colonies of *Euphilotes enoptes smithi* within Monterey County, California. Colonies are numbered 1-16 as follows. Colonies in coastal canyons include **1)** 6.4 km N Pt. Gorda, **2)** 6.4 km SE Lucia, **3)** 4.8 km SE Lucia, **4)** Landells Hill-Big Creek Preserve, **5)** Burns Creek (Type Locality), **6)** Partington Canyon, and **7)** several canyons along California Highway 1 between Malpaso and Garrapta Creeks. Colonies on sand dunes include **8)** Pt. Lobos State Park, **9)** Monterey "sand hills" (extirpated), **10)** Seaside (largely extirpated), **11)** Ft. Ord, **12)** Marina Beach dunes, and **13)** California Department of Fish & Game Ecological Reserve. Colonies at inland sites include **14)** Vasquez Knob, **15)** near Carmel Valley Village, and **16)** near Paraiso Springs. State highways depicted are numbers 1, 156, and 183. Monterey County roads figured are G16 and G17. One interstate highway, 101, is noted.

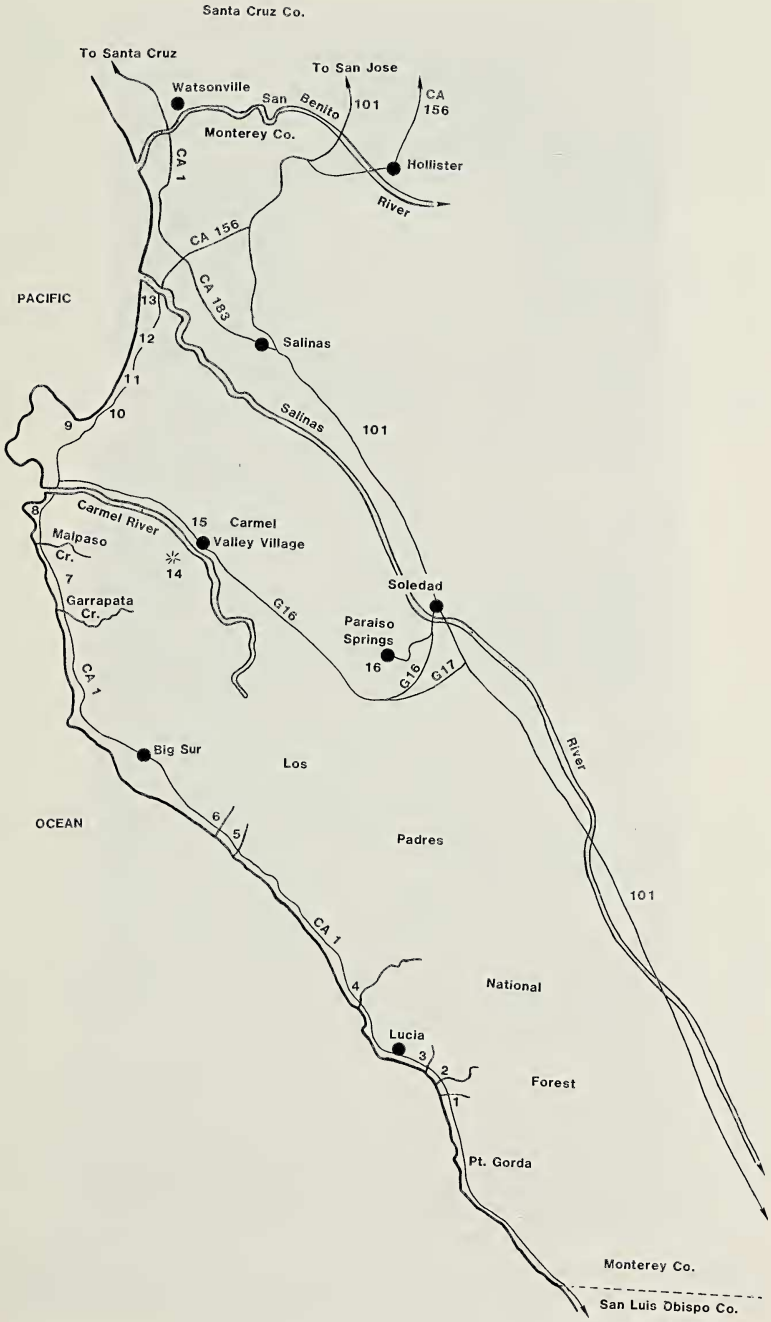
Santa Cruz Co.
To Santa Cruz
To San Jose
Watsonville
San Benito
101
CA 156
Monterey Co.
CA 1
Hollister
River
CA 156
CA 183
PACIFIC
13
12
11
10
9
Salinas
Salinas
101
8
Carmel River
15
Carmel
Valley Village
Malpaso Cr.
14
7
Garrapata Cr.
G16
Soledad
Paraiso Springs
16
G16
G17
CA 1
Big Sur
Los
OCEAN
6
5
Padres
River
101
CA 1
4
National
Lucia
3
2
Forest
1
Pt. Gorda
Monterey Co.
San Luis Obispo Co.

Fig. 3. U.S. Army endangered species preserve sign for the northern dune preserve (study site NP) at Ft. Ord.

The formation and maintenance of a sand dune depend upon a variety of dynamic and interacting processes. Generally there are 3 zones or land forms which comprise a coastal dune: 1) foredunes, 2) deflation plain, and 3) stabilized dunes (Barbour and Johnson, 1977). At several *smithi* dune localities only 1 or 2 zones exist. The process of plant succession on Monterey peninsula dunes was described by McBride and Stone (1976).

During 1977-1981, two dune preserves at Fort Ord served as study sites for population investigations on *smithi*: the North Preserve (NP) and South Preserve (SP). These areas were designated preserves (Figs. 3, 4) in 1967 to protect examples of the natural ecosystems located on the U.S. Army base (Griffin, 1976). Fifteen rare or listed endangered plants, reptiles, and an insect are known from various preserves on the base. It was fortuitous that NP and SP became the first federal insect preserves in the United States since they were designated preserves nearly 10 years before the Smith's Blue butterfly was recognized as an endangered species.

Coastal strand plus numerous exotic species, especially *Mesembryanthemum* and *Ammophila*, comprise the dominant vegetation at these

stabilized dunes (Table 1). *Eriogonum latifolium* Benth. (Fig. 5) is the foodplant for *smithi* at NP, while *E. parvifolium* (Fig. 6) is the foodplant at SP. NP is less stabilized by exotic vegetation than SP. The extent of active sand areas at both sites coincides with the location of *Eriogonum*, whereas stabilized areas correspond to the distribution of *Mesembryanthemum*, *Ammophila*, and coastal strand vegetation. Arnold (1980) gives vegetation maps for SP and NP.

Dune ecology involves a number of dynamic processes that create a balance between stability and movement of sand. Many of the woody perennial plants characteristic of dunes are dependent upon secondary deposit of aeolian sand for the establishment and growth of their seedlings. Small dune remnants frequently lack a nearby reservoir of sand and become further stabilized by weedy plants, which often outcompete endemic perennials and prevent establishment of seedlings by native

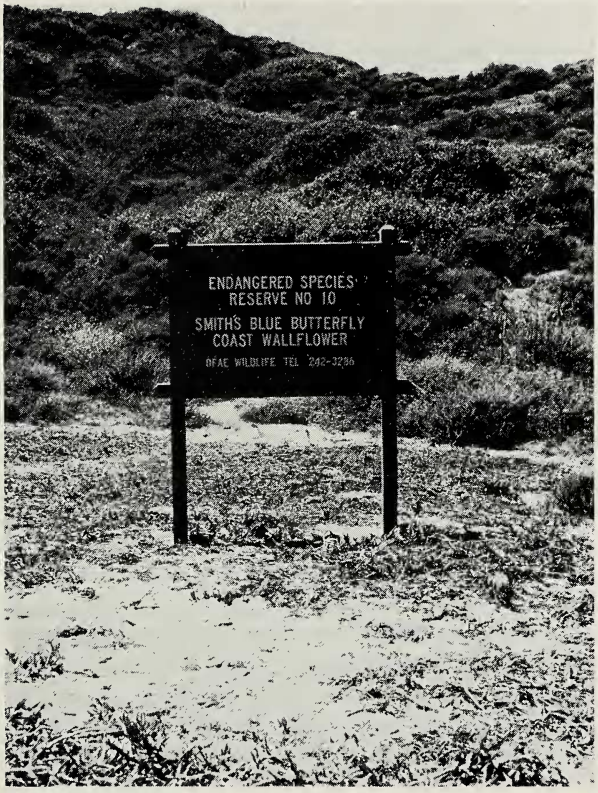

Fig. 4. **a.** U.S. Army endangered species preserve sign for the southern dune preserve (study site SP) at Ft. Ord.
b. Coastal strand vegetation characteristic of SP.

species, for example, allelopathic *Mesembryanthemum* (Fig. 7) species (Vivrette and Muller, 1977). *Ammophila arenaria* also outcompetes native flora. The diversity of insect life characteristically associated with native plants on natural dune systems is drastically reduced in dense stands of *Ammophila* (Slobodchikoff and Doyen, 1977).

Powell (1981) notes that along the California coastline northern dune plant communities are more mesic while southern communities are more xeric. Species diversity of dune flora is greater in northern California (13-15 species) than in southern coastal dune areas (8-10 species). Floristically, the central portion of the California coastline, particularly the Monterey area, exhibits the greatest species diversity with 20-22 species. *Eriogonum laifolium* is a member of the northern California dune flora, whereas *E. parvifolium* is representative of the southern California flora. NP is comprised of plants representing the northern dune flora. In contrast, SP which is only 5.5 km south of NP, is characterized by a southern flora.

Life History and Behavior

Euphilotes enoptes smithi is univoltine. At Fort Ord, adults at study site NP emerge from mid-June until early August; at SP from mid-July until early September. Adult emergence is synchronized with the peak flowering period of *E. latifolium* at NP and *E. parvifolium* at SP. Both buckwheats are utilized as larval and adult foodplants.

Adult males and females live approximately one week. Both sexes spend the majority of their time on *Eriogonum* flowerheads either perching or obtaining nectar. Mate location, copulation and oviposition also occur on *Eriogonum* flowerheads.

There are five larval instars. Approximately one month is spent as a larva. The 3rd, 4th, and 5th instar larvae (Fig. 9) are tended by ants. For additional bionomic information consult Arnold (1978, 1980, and 1981).

Two host races or ecotypes of *E. enoptes smithi* were discerned at coastal dune areas, one feeding on *E. latifolium* and the other on *E. parvifolium* (Arnold, 1980). Peak flowering period for the former buckwheat species preceeds that of the latter by approximately 3-4 weeks. Adult emergence and larval developmental times are synchronized with the flowering period of respective foodplants. Thus the sequence of life history events for butterflies at NP and SP are partially allochronically asynchronous. Despite their geographic proximity, this phenomenon represents a potential isolating mechanism between the NP and SP populations. Future studies will be necessary to assess the effectiveness of this isolating mechanism. In other insects, similar circumstances have resulted in sympatric speciation (Bush, 1974; Tauber and Tauber, 1978).

Comparably intensive ecological studies have not been undertaken on coastal montane populations of *Euphilotes enoptes smithi*. Additional ecotypes may be found in these populations.

TABLE 1

Principal plant species at NP and SP study sites. Familial arrangement after Munz and Keck (1968).

Euphorbiaceae
Croton californicus Muell-Arg.
Papaveraceae
Eschscholtzia californica Cham. var. *maritima* (Greene) Jepson
Cruciferae
Cakile maritima Scop.
Erysimum ammophilum Heller
Aizoaceae
Mesembryanthemum chilense Mol.
M. edule L.
M. chilense Mox. X *M. edule* L.
Nyctaginaceae
Abronia latifolia Eschs.
A. umbellata Lam.
Convolvulaceae
Convolvulus soldanella L.
Scrophulariaceae
Orthocarpus purpureus Benth. var. *pallidus* Keck
Castilleja latifolia H. & A.
Leguminosae
Lupinus albifrons Benth.
L. arboreus Sims.
L. chamissonis Eschs.
Lotus heermannii (Dur. & Hilg.) Greene
Lathyrus littoralis (Nutt. *ex* T. & G.) Endl.
Onagraceae
Camissonia cheiranthifolia Hornem. *ex* Spreng.
Compositae
Ambrosia chamissonis Less.
Artemisia pychnocephala DC.
Cirsium occidentale (Nutt.) Jepson
Corethrogyne leucophylla Jepson
Eriophyllum staechadifolium Lag.
Haplopappus eriocides (Less.) H. & A.
Gramineae
Poa douglasii Nees.
Elymus mollis Trin. *ex* Spreng.
Ammophila arenaria (L.) Link

TABLE 2

Summary of capture-recapture results on *Euphilotes enoptes smithi* during 1977-1979. The legend is as follows: numbers of individuals marked (N), residency estimates (R) (measured in days), percent of marked individuals recaptured (%R), and total estimated population numbers (TOTALS).

	N		R		%R		TOTALS	
SAMPLE	♂	♀	♂	♀	♂	♀	♂	♀
1977NP	551	379	3.5	2.5	31.0	25.1	1777	1510
1978NP	826	641	2.6	4.5	30.3	25.9	2726	2475
1979NP	845	647	6.3	6.5	49.9	46.6	1693	1388
1978SP	556	404	3.5	5.9	36.2	33.2	1536	1217

Population Dynamics

Capture-recapture studies on adults were conducted during 7-18 July 1977, 27 June-12 July 1978 and 1-18 July 1979 at NP and 16-28 July 1978 at SP. Details on methodology are explained in Arnold (1980, 1982b). Data collected from these studies were used to calculate daily population numbers, lifespan (residency), vagility parameters, sex ratios, dispersion and home range (standard area of activity).

A total of 2,778 males and 2,071 females was marked during the capture-recapture studies. Each study revealed more males than females among newly captured individuals and in daily sample totals (i.e., numbers marked and recaptured). The sex ratio for the total estimated population was 57.3% males:42.7% females.

Daily NP population (males + females) estimates ranged from 97-1035 individuals in 1977, 30-1045 in 1978, and 45-1065 in 1979. Estimated total seasonal population sizes during the 3 sampling periods fluctuated between 3,000-5,200 individuals at NP (Table 2). In contrast, daily population estimates at SP, where estimated total seasonal population size was 2,753 individuals (Table 2) never exceeded 600 individuals during 1978.

Mean expected residencies indicated that females (grand mean 5.8 days) lived slightly longer than males (grand mean 4.0 days). Females might be expected to have lower average residencies due to their greater vagility. Longer movements should increase the chance that females emigrate from the study site. However both sexes are quite sedentary compared to other butterflies (Scott, 1975; Ehrlich *et al.*, 1975; Brussard and Ehrlich, 1970; Watt, *et al.*, 1977; Hafernik, 1976). Average daily movements for females were $\leq$47.5 m. and for males were $\leq$34.4 m. Approximately 75% of all

observed movements were ≤23.0 m. The maximum movement for any individual was 226 m.

The home range or standard area of activity (SAA) for males ranged from 0.0-2.7 ha, with a mean for all samples of 0.9 ha. Female SAA's ranged from 0.2-3.5 ha with a mean of 1.3 ha. Approximately 2.3 ha of suitable habitat was available at NP and 4.8 ha at SP. Thus a typical male at NP utilized about 39% of the potentially occupied area, while females utilized approximately 57%. At SP, the typical male utilized about 26% and a female 35% of the total suitable habitat.

Conservation and Management of the Smith's Blue Butterfly

Despite its recognition as a federally endangered species, the habitat of *Euphilotes enoptes smithi* continues to decline. Since the turn of the century, over 50% of the original dune habitat in the immediate Monterey area has been destroyed by man (Powell, 1981). Another and perhaps greater threat to its long-term survival on coastal dune systems is the extensive and rapid alteration of natural vegetation and dynamic features of undisturbed sand dunes by exotic plants.

One purpose of ESA 1973 is to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved. Thus the act directs the Secretary of Interior to develop and implement recovery plans for the conservation and survival of endangered species. The recovery plan serves as a guide for governmental agencies which "justifies, delineates, and schedules those actions required for restoring and securing an endangered or threatened species as a viable self-sustaining member of its ecosystem." Now is the time to identify and implement measures necesseary to protect, maintain, and rehabilitate the unique habitats of *smithi*, before its situation deteriorates like that of its relative, *Euphilotes battoides allyni* (Shields). Unlike its congener, *Euphilotes battoides allyni*, which survives on only 33 ha at the Los Angeles International Airport and Chevron Refinery in El Segundo (Arnold, 1982a and b), populations of the Smith's Blue butterfly are distributed over an area encompassing several hundred square kilometers.

The remaining portion of this section describes actions necessary for recovery of *Euphilotes enoptes smithi*. These collective actions are herein referred to as a conservation plan, rather than a recovery plan, since this is not an official document of OES/USFWS.

Conservation Plan for the Smith's Blue

Objectives and Rationale.

Euphilotes enoptes smithi is classified as an endangered species by USFWS because of habitat destruction and degradation. Arresting the decline of this butterfly requires prevention of further loss or alteration of existing habitat. The primary objective of this conservation plan is to

maintain known populations of *smithi* through a coordinated program of habitat preservation, rehabilitation and management. Essential requirements for the conservation of *smithi* and actions to accomplish these objectives are identified.

Integral to the conservation plan is the establishment of a management program for the Smith's Blue butterfly under which essential habitat is protected, maintained, and rehabilitated. Actions proposed to achieve these objectives are presented as a flowchart (Fig. 10). The activities proposed are divided into 5 categories: 1) protection and preservation of existing habitat sites, 2) implementation of short-term and long-term management policies, 3) development of monitoring programs to annually survey and census selected populations to determine the success of management efforts, 4) promotion of public awareness of the butterfly and its unique habitat, and 5) enforcement of federal, state, and local laws or regulations to protect *smithi*. Specific actions within each category are enumerated. Numbers in parentheses refer to specific tasks on the conservation plan flowchart (Fig. 10). These recommendations are based upon the best available information. However this conservation plan should be reviewed regularly and up-dated as new information accrues.

Protection and Preservation of Existing Habitat.

Several known habitat sites are owned by municipal, state or federal agencies (111, 117), e.g., Marina Beach by the City of Marina (114), Landels-Hill Big Creek reserve by the University of California (125), and Fort Ord by the U.S. Army. Several of these land owners are cognizant of the presence of *smithi* on their properties and have expressed a desire to participate in protection and management efforts. Preservation of publicly owned parcels can be arranged via cooperative agreements or memoranda of understandings (MOU's) between the agencies responsible for protection of the butterfly, USFWS and California Dept. of Fish & Game (CDFG), and respective land owners (1, 11). Privately owned habitat sites require other measures to insure their protection (114, 115, 116, 118, 119, 120, 121, 122, 123, 124). Cooperative agreements or MOU's may be sufficient to secure one or more of these sites, while purchase or conservation easements may be necessary to protect other sites.

Critical habitat for an endangered species is defined by ESA 1973 as the area containing those features essential to conservation of the species and alerts other federal agencies to the presence of an organism of concern. State or private actions that do not involve federal funding or require federal approval *may* be exempt from compliance with regulations under ESA 1973. For example, state and private concerns are exempt from compliance with Section 7 of the ESA 1973, which describes interagency cooperation and consultation processes. However, state and private concerns must comply with Section 9, Prohibited Acts, which includes killing or harming a listed endangered species. Critical habitat was

proposed for *Euphilotes enoptes smithi* in February 1977, but the designation was not finalized because the time limit for a rulemaking expired. Since then several additional colonies of *smithi* have been discovered and listing requirements have been changed. Now economic as well as biological factors must be considered in proposing critical habitat. Reproposal of critical habitat (13) should probably be delayed until 1) further survey work is completed to delimit the entire range of *smithi* and its ecotypes (14), and 2) taxonomic questions regarding the Santa Barbara and Santa Cruz County populations are resolved (15).

Maintenance of Existing Habitat.

White and Bratton (1980) noted that after habitats are legally protected, an array of ecological changes continue to affect species and ecosystems, including a) natural and human-induced, b) beneficial and detrimental, and c) from manageable to non-manageable. Many of the and dune, canyon and rocky hillside habitat sites of *smithi* have been altered or degraded by various factors discussed earlier. Mere protection of these sites will not be adequate to halt further large-scale ecological degradation of existing habitats. Intelligent management will be essential to preserve *Euphilotes enoptes smithi* at these sites.

A number of short- and long-term management activities will be necessary. Initially, preventive maintenance is required to sustain requisite larval and adult resoures at all known localities (12). In part, this can be accomplised by minimizing use of toxic substrates (121), ORV activity (122) and the planting of exotic vegetation (123). Long-term management activities should, in addition to the above factors, focus on rehabilitating habitat and reducing effects of other unnatural limiting factors (2, 21, 211, 2111, 214, 22). Control or removal of noxious and weedy plants which exclude *Eriogonum* and other endemics is desirable (21111). Alien plants are responsible for stabilization of much of the remaining sand dune habitat. Secondary redeposit of aeolian sands is minimal, thus natural seedling establishment of *Eriogonum* and other dunes endemic plants has been limited (Arnold, 1980; Powell, 1981). If natural reestablishment does not occur (21112), propagation and transplanting might be necessary (21112). At coastal canyon and montane sites, rock slides may be important in the establishment of *Eriogonum* seedlings. This and other perturbation factors require elucidation. Likewise, only a limited amount of information on the physical and climatic factors of habitat sites is known (2113). McBride and Stone (1976) discussed such characteristics for Monterey area sand dunes. Similar information for coastal canyon and mountainous areas is needed.

Additional Research.

Euphilotes enoptes smithi undoubtedly occurs at several heretofore undiscovered localities in coastal canyons and mountains of Monterey

County. Due to the inaccessibility of this rugged region, a thorough ground level survey may be impossible. However, an aerial survey, performed in a helicopter at a ceiling height < 500 ft. would probably be adequate to map larger patches of *Eriogonum*. Follow-up ground reconaissance could determine the status of *smithi* at new localities (14). I suggest that the aerial survey be conducted during July and August, when *Eriogonum latifolium* and *E. parvifolium* bloom and would be most conspicuous.

The uncertain taxonomic status of *Euphilotes enoptes* populations in Santa Cruz and Santa Barbara counties must be resolved (15). If they are determined to be *smithi*, then the above mentioned survey work should be expanded to also include these regions. If these outlier populations are consubspecific, OES/USFWS might decide to downlist *smithi* to threatened species status, or remove it from the endangered species list.

Autecological research completed to date has focused on two sand dune ecotypes of *smithi* (Arnold, 1978, 1980). Similar investigations should be performed on one or more montane and canyon populations (212, 2121, 2122, 2123, 2124, 2125, 2126). Preliminary comparisons of sand dune and chaparral ecotypes revealed differences in vegetation types, density of the host *Eriogonum*, habitat size, intra- and inter-patch sizes of the *Eriogonum*, and utilization of secondary nectar resources. Differences in these characteristics are likely to influence the population structure, numbers, and dispersal abilities of *smithi* ecotypes, factors which must be understood for implementation of adequate conservation and management practices. In addition, the role of ants in protecting larvae requires further investigation (2122).

Several sand dune localities for *smithi* require extensive rehabilitation. A basic requirement for the conservation of *Euphilotes enoptes smithi* and its sand dune ecosystem is the revegetation by native plant species and the elimination of exotic flora. Study sites should be established and a variety of techniques explored to assess the most cost effective and ecologically compatible means to improve habitat conditions (2112). Research by McBride and Stone (1976) should offer preliminary guidelines. In addition, growth data on *Eriogonum* and other endemic plants are needed for propagation, rehabilitation, and management studies. Autecological studies on *Eriogonum* and selected endemic species would provide insight into propagation, rehabilitation and management efforts, and especially provide baseline data to design annual survey methods to measure the success of these efforts (213, 2131, 2132, 2133, 2134).

Due to the different characteristics of the *smithi* ecotypes, habitat sites and number of localities, the accumulated data should be utilized to devise a computer simulation model to assist in formulating management policies and optimize management strategies (221). This model would permit analyses to be performed by the computer rather than on-site and would provide valuable insight into rehabilitation and management actions.

Census techniques must be developed to periodically monitor the status of *Euphilotes enoptes smithi* with minimal expenditure of time and personnel (3, 31). Capture-recapture data of Arnold (1978, 1980, 1982b) could be used to construct a catch-per-effort model (311, 312). Craig's (1953) method for assessing population numbers, as well as other censusing techniques should be rigorously evaluated for accuracy compared to capture-recapture models of Jolly-Seber (Jolly, 1965; Seber, 1965), Manly-Parr (Manly and Parr, 1968), and Fisher-Ford (Fisher and Ford, 1947). Initially I would suggest that several methods be tested simultaneously and the results compared to estimates of capture-recapture models. After suitable census methods are devised, it would also be advisable to periodically conduct a capture-recapture study, perhaps every 4 to 5 years, to re-evaluate the accuracy of other census methods.

EDUCATION ACTIVITIES

Protection of *Euphilotes enoptes smithi* plus its dune and chaparral habitats could be greatly facilitated by increased public awareness (4). Once habitat sites are secured, interpretive tours, displays and publications should be prepared and offered to the general public (41, 42, 421, 422, 423). Although this conservation plan has focused attention on the Smith's Blue butterfly, habitat protection and management combined with increased public awareness will benefit many other endemic wildlife and plant species of concern. Two rare lizards are known from sand dunes on the Monterey peninsula. The California Native Plant Society recognizes the dune endemic wallflower, *Erysimum ammophilum* Heller, as an endangered species. In the meantime, all laws and regulations which provide protection for *smithi* should be enforced (5).

Fig. 10. Conservation plan for the Smith's Blue butterfly. Although management policies refer primarily to coastal sand dune habitats, similar activities should be undertaken at the coastal canyon and inland sites.

FLOWCHART:

Prime Objectives: preserve and enhance presently known Smith's Blue Butterfly (SBB) populations in Monterey County, California, through an integrated program of habitat protection and management; survey other sites to discover additonal colonies; undertake biological studies to provide further insight with management policies.

1. Preserve, protect, and manage existing habitat to provide adequate conditions for existing SBB populations.
   11. Preserve known habitat sites by preventing further degradation, development,or environmental modification, through a) cooperative agreements, b) memoranda or understandings, c) conservation easements

between USFWS/CDFG and respective land owners, d) acquisition through purchase or donation, or e) cooperative agreement with the California Coastal Commission.

111. CDFG Ecological Preserve
112. Marina Beach dunes
113. Ft. Ord dunes
114. Seaside dunes
115. Pt. Lobos State Park
116. Vasquez Knob
117. Paraiso Springs
118. Carmel Valley
119. Burns Creek
120. 6.4 km N Pt. Gorda
121. 6.4 km SE Lucia
122. 4.8 km SE Lucia
123. Landels-Hill Big Creek Reserve
124. Partington Canyon
125. Coastal canyons between Malpaso and Garrapata Creeks

12. Maintain requisite larval and adult resources at all known habitat sites.
    121. Minimize use of herbicides, insecticides, and other toxic substances.
    122. Minimize ORV activity.
    123. Minimize plantings of exotic vegetation.
13. Propose Critical Habitat.
14. Survey additional sites along Monterey County coastline and inland areas for presence of *Eriogonum* and SBB populations, and arrange appropriate protection.
15. Clarify taxonomic status of outlier populations (i.e., Santa Cruz and Santa Barbara County *Euphilotes enoptes*).

2. Manage and enhance known SBB populations by maintaining habitat size, improving habitat quality, and reducing effects of other limiting factors.
    21. Devise and implement interim management plans.
        211. Investigate and initiate habitat improvement methods as appropriate.
            21111. Remove or control undesirable noxious and weedy plants from sites which outcompete *Eriogonum* and other dune endemic plants.
            21112. Promote natural seedling establishment of *Eriogonum* and other endemic plants.
            21113. If necessary, propagate and transplant native plants.
        2112. Conduct research to determine most ecologically compatible and cost-effective techniques for habitat improvement.

2113. Determine physical (ex., edaphic conditions, slope, etc.) and climatic (ex., precipitation, temperature, etc.) factors of habitat sites and relate to habitat improvement actions.

212. Conduct additional research on SBB autecology for each of the three ecotypes.

2121. Life History.

2122. Role of ants in protection of larvae from predators and parasites.

2123. Population structure.

2124. Adult behavior; mating, foraging, oviposition, etc.

2125. Determine predators, parasitoids, and other limiting factors.

213. Conduct autecological research on bionomics of *Eriogonum parvifolium* and *E. latifolium*.

2131. Life History.

2132. Determine mortality factors.

2133. Determine limiting factors, such as edaphic conditions, slope, exposure, etc.

2134. Conduct horticultural studies to determine propagation techniques, if necessary.

214. Conduct autecological research on tending ant species.

22. Evaluate data and incorporate findings into the development of long-term management plans.

221. Devise a computer simulation model to assist in management decisions.

3. Monitor SBB populations to determine status and success of management.

31. Conduct annual surveys to monitor SBB populations.

311. Develop suitable survey methods to estimate population numbers, distribution, and population trends.

312. Determine sites to be surveyed.

4. Increase public awareness of SBB through education and information programs.

41. Establish information signs at known habitat sites and offer interpretive tours of one or more sites.

42. Establish audio and visual programs and publications.

421. Prepare TV and radio spot programs.

422. Prepare audio-visual display on SBB preservation and management program.

423. Prepare conservation education program on SBB natural history.

5. Enforce laws and regulations to protect SBB.

Acknowledgments. The Permit Branch of the Office of Endangered Species (U.S. Fish & Wildlife Service) and the California Department of Fish & Game kindly provided necessary permits to conduct this research. I thank Drs. Paul A. Opler,

Michael Bentzien, Larry L. Eng, and Mr. Howard Leach for their assistance in securing permits and research funding. Financial support was provided by the California Department of Fish & game (Contract S-1620) and the Theodore Roosevelt Memorial Fund Fellowship of the American Museum of Natural History. The College of Natural Resources, University of California at Berkeley, provided funds for computer time. Paul Dubsky and Jack Masara arranged for access to my Fort Ord study sites. Bruce Walsh and Debbie Arnold assisted with field work. Michael Bentzien and Larry L. Eng reviewed an early draft of this paper and improved its content and readability.

Literature Cited

ARNOLD, R. A., 1978. Survey and status of six endangered butterflies in California. California Department of Fish and Game report. 95 pp.

_____, 1980. Ecological studies of 6 endangered butterflies: island biogeography, patch dynamics and the design of nature preserves. Ph.D. thesis, University of California, Berkeley. 365 pp.

_____, 1981. A review of endangered species legislation in the U.S.A. and preliminary research on 6 endangered California butterflies (Lepidoptera: Lycaenidae). *In*, Biotop- und Artenschutz bei Schmetterlingen. G. Schmid (ed.). Beih. Veroff. Naturschutz Landschaftspflege Bad.-Wurtt. Karlsruhe. pp. 79-96.

_____, 1982a. El Segundo blue butterfly recovery plan. U.S. Fish and Wildlife Service, Endangered Species Office (in press).

_____, 1982b. Ecological studies of 6 endangered butterflies (Lepidoptera: Lycaenidae): island biogeography, patch dynamics and the design of nature preserves. Univ. Calif. Publ. Entomol. (in press).

BARBOUR, M. G. & A. F. JOHNSON, 1977. Beach and dune. *IN*, M. G. Barbour and J. Major (eds.). Terrestrial vegetation of California. John Wiley & Sons, New York. pp. 223-262.

BRUSSARD, P. F. & P. R. EHRLICH, 1970. The population structure of *Erebia epipsodea*. Ecology 51:119-129.

BUSH, G. L. 1974. The mechanism of sympatric host race formation in the true fruit flies (Tephritidae). *IN*, M.J.D. White (ed.). Genetic mechanisms of speciation in insects. Australia and New Zealand Book Co., Sydney. pp. 3-23.

CRAIG, C. C., 1953. On the utilisation of marked specimens in estimating population of flying insects. Biometrika 40:170-176.

EHRLICH, P. R., R. R. WHITE, M. C. SINGER, W. W. McKECHNIE & L. E. GILBERT, 1975. Checkerspot butterflies: a historical perspective. Science 188:221-228.

EMMEL, T. C. & J. F. EMMEL, 1973. The butterflies of Southern California. Nat. Hist. Museum, Los Angeles County, Sci. Series.

FISHER, R. A. & E. B. FORD, 1947. The spread of a gene in natural conditions in a colony of the moth *Panaxia dominula* L. Heredity 1:143-174.

GRIFFIN, J. R., 1976. Native plant reserves at Fort Ord. Fremontia 4(2):25-28.

HAFERNIK, J. E., 1976. Phenetics and ecology of hybridization in buckeye butterflies. Ph.D. thesis, Univ. Calif., Berkeley. 210 pp.

HOWE, W. H. (ed.). 1975. The butterflies of North America. Doubleday & Co., Inc. New York.

HYLGAARD, T., 1980. Recovery of plant communities on coastal sand-dunes disturbed by human trampling. Biol. Conserv. 19:15-25.

HYLGAARD, T. & M. J. LIDDLE, 1981. The effect of human trampling on a sand dune ecosystem dominated by *Empetrum nigrum*. J. Appl. Ecology 18:559-569.

JOLLY, G. M., 1965. Explicit estimates from capture-recapture data with both death and immigration - stochastic model. Biometrika 52:225-247.

LANGSTON, R. L., 1963. *Philotes* of central coastal California (Lycaenidae). J. Lepid. Soc. 17:201-223.

_____, 1965. Distribution and hosts of five *Philotes* in California (Lycaenidae). J. Lepid. Soc. 19:95-102.

MANLY, B. F. J. & M. J. PARR, 1968. A new method of estimating population size survivorship, and birth rate from capture-recapture data. Trans. Soc. Brit. Entomol. 18:81-89.

MATTONI, R. H. T., 1954. Notes on the genus *Philotes*. I. Descriptions of 3 new subspecies and a synoptic list. Bull. So. Calif. Acad. Sci. 53:157-165.

_____, 1977. The Scolitantidini: I. Two new genera and a generic rearrangement (Lycaenidae). J. Res. Lepid. 16:223-242.

McBRIDE, J. R. & E. C. STONE, 1976. Plant succession on the sand dunes of the Monterey Peninsula, California. Amer. Midl. Natur. 96:118-132.

MUNZ, P. A. & D. D. KECK, 1968. A California flora, with supplement. Univ. Calif. Press, Berkeley.

POWELL, J. A., 1981. Endangered habitats for insects: California coastal sand dunes. Atala 6:41-55.

SCOTT, J. A., 1975. Flight patterns among eleven species of diurnal Lepidoptera. Ecology 56:1367-1377.

SEBER, G. A., 1965. A note on multiple-recapture census. Biometrika 52:249-259.

SENECA, E. D., 1980. Dune community creation along the Atlantic Coast. *IN*, Lewis, J. C. and E. W. Bunce (eds.). Rehabilitation and creation of selected coastal habitats: Proceedings of a workshop. U.S. Fish and Wildlife Service, Biological Services Program. Washington, D.C. FWS/OBS-80/27.

SHIELDS, O., 1975. Studies on North American *Philotes*. IV. Taxonomic and biological notes, and new subspecies. Bull. Allyn Museum. No. 28.

SLOBODCHIKOFF, C. N. & J. T. DOYEN, 1977. Effects of *Ammophila arenaria* on sand dune arthropod communities. Ecology 58:1171-1175.

SMITH, M., 1978. Season's Summary for 1977. Region I. Western U.S., California. Lepid. Soc. News. Jan.-Feb. issue. p. 5.

TAUBER, C. A. & M. J. TAUBER, 1978. Sympatric speciation based on allelic changes at three loci: evidence from natural populations in two habitats. Science 197: 1298-1299.

U.S. FISH & WILDLIFE SERVICE, 1976. Determination that six species of butterflies are endangered species. Fed. Regist. 41:22041-22044.

VIVRETTE, N. J. & C. H. MULLER, 1977. Mechanism of invasion and dominance of coastal grassland by *Mesembryanthemum crystallinum*. Ecol. Monogr. 47:301-318.

WATT, W. B., F. S. CHEW, L. R. G. SNYDER, A. G. WATT, & D. E. ROTHSCHILD, 1977. Population structure of Pierid butterflies. I. Numbers and movements of some montane *Colias* species. Oecologia 27:1-22.

WHITE, P. S. & S. P. BRATTON, 1980. After preservation: philosophical and practical problems of change. Biol. Conserv. 18:241-255.